US010832208B2

(12) **United States Patent**
Souder et al.

(10) **Patent No.: US 10,832,208 B2**
(45) **Date of Patent: Nov. 10, 2020**

(54) **SYSTEMS AND METHODS FOR FACILITY MATCHING AND LOCALIZATION**

(71) Applicant: **BXB Digital Pty Limited**, Sydney (AU)

(72) Inventors: **Michael Souder**, Fremont, CA (US); **Ryan Daigle**, Fremont, CA (US); **Shankar Jayaraman**, Fremont, CA (US); **Raj Valame**, Palo Alto, CA (US)

(73) Assignee: **BXB DIGITAL PTY LIMITED**, Sydney (AU)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 228 days.

(21) Appl. No.: **15/969,159**

(22) Filed: **May 2, 2018**

(65) **Prior Publication Data**

US 2018/0322446 A1 Nov. 8, 2018

Related U.S. Application Data

(60) Provisional application No. 62/500,461, filed on May 2, 2017.

(51) **Int. Cl.**

H04W 64/00	(2009.01)
G06K 17/00	(2006.01)
G06Q 10/08	(2012.01)
G06F 16/955	(2019.01)
G06F 16/9537	(2019.01)
G06Q 50/28	(2012.01)

(52) **U.S. Cl.**

CPC ***G06Q 10/087*** (2013.01); ***G06F 16/955*** (2019.01); ***G06F 16/9537*** (2019.01); ***G06Q 10/0833*** (2013.01); ***G06Q 50/28*** (2013.01)

(58) **Field of Classification Search**

CPC ... G06Q 10/087; G06Q 10/08; G06K 17/0029

See application file for complete search history.

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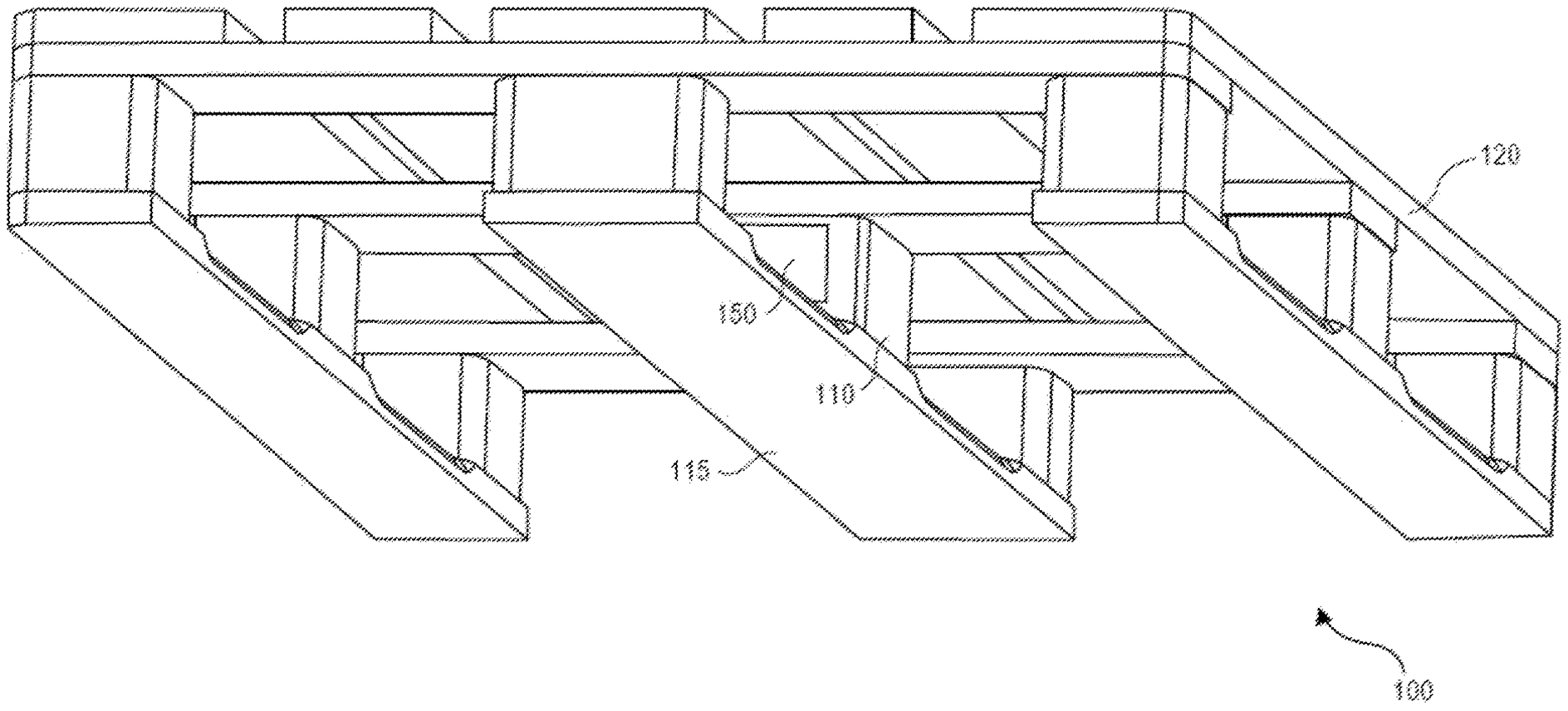
Primary Examiner — Talia F Crawley

(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend & Stockton LLP

(57) **ABSTRACT**

Provided are methods, including computer-implemented methods, devices, and computer-program products applying systems and methods for facility matching and localization. According to some embodiments of the invention, the location of a pallet at a facility within a supply chain may be determined from location data received from a beacon on the pallet. In some embodiments, the position of the pallet within the facility may also be determined. Thus, the status of pallets may be monitored as they move through the supply chain.

20 Claims, 7 Drawing Sheets



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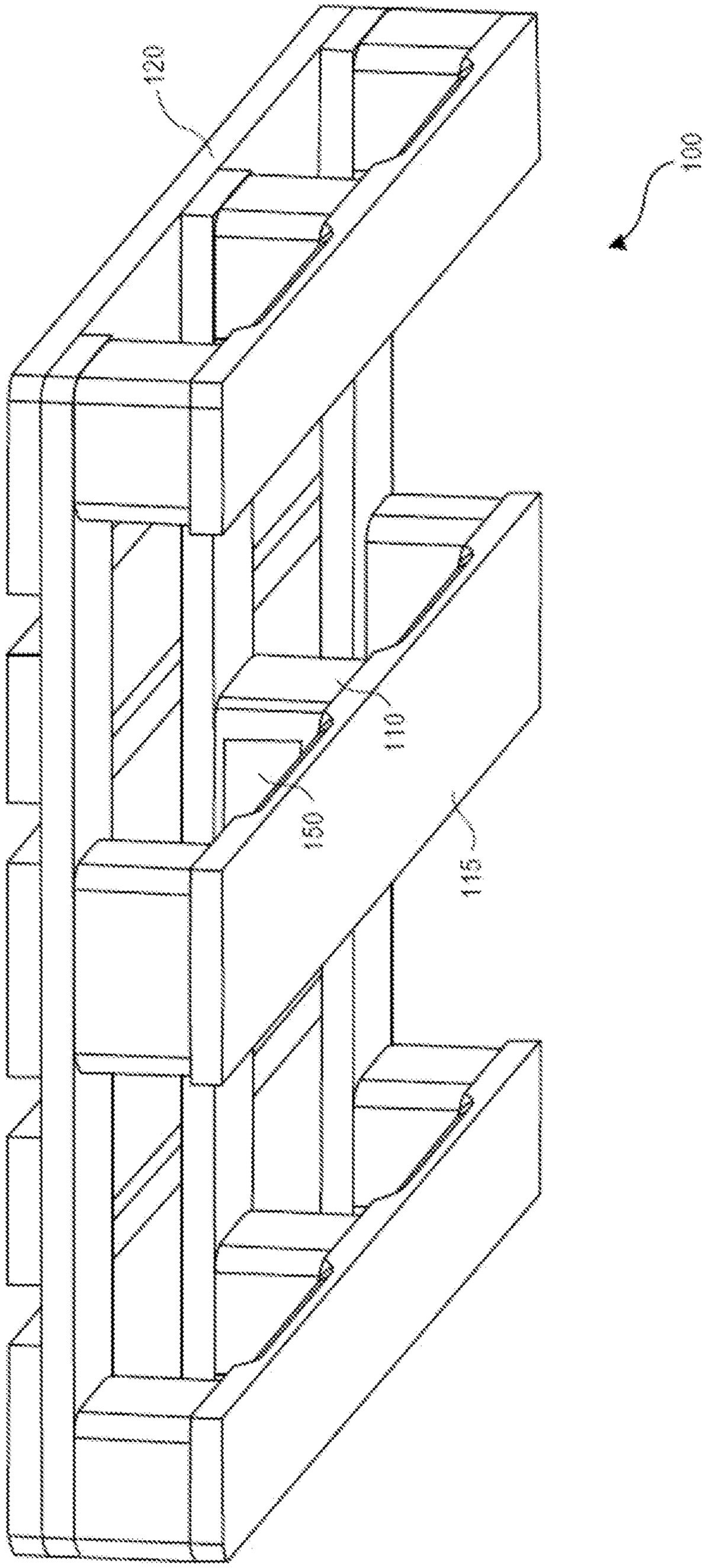

FIG. 1

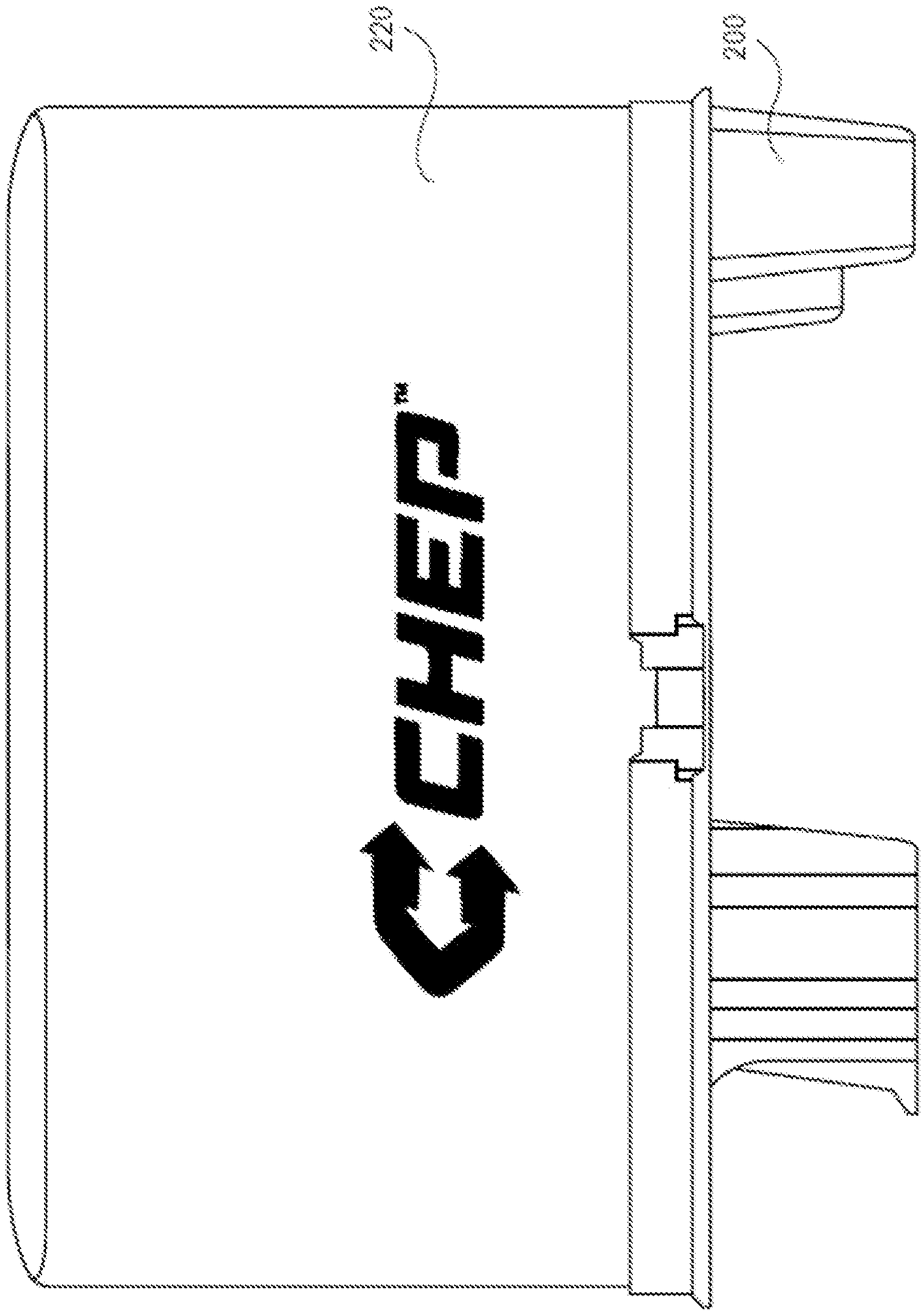

FIG. 2

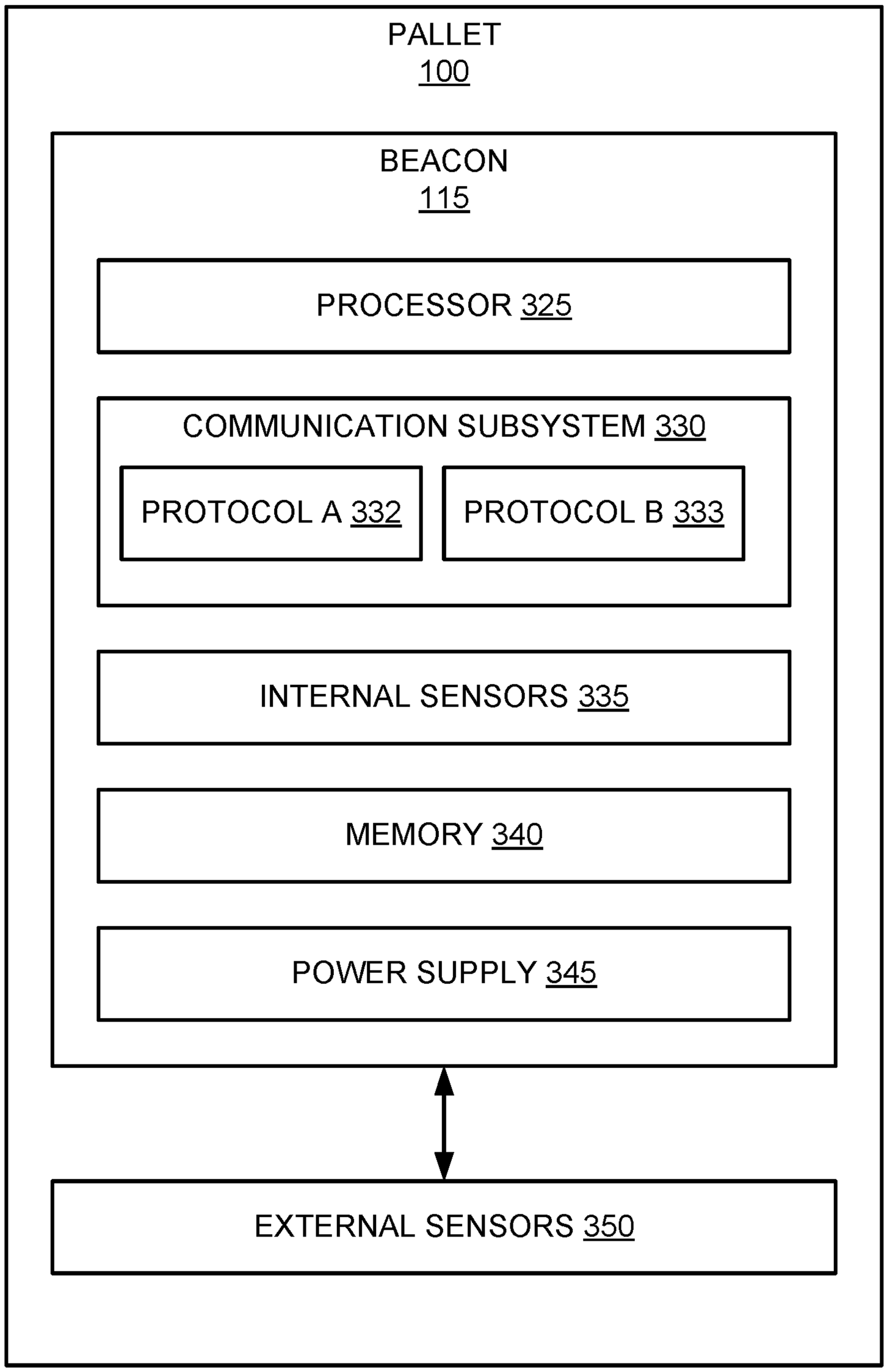
PALLET
100
BEACON
115
PROCESSOR 325
COMMUNICATION SUBSYSTEM 330
PROTOCOL A 332
PROTOCOL B 333
INTERNAL SENSORS 335
MEMORY 340
POWER SUPPLY 345
EXTERNAL SENSORS 350

FIG. 3

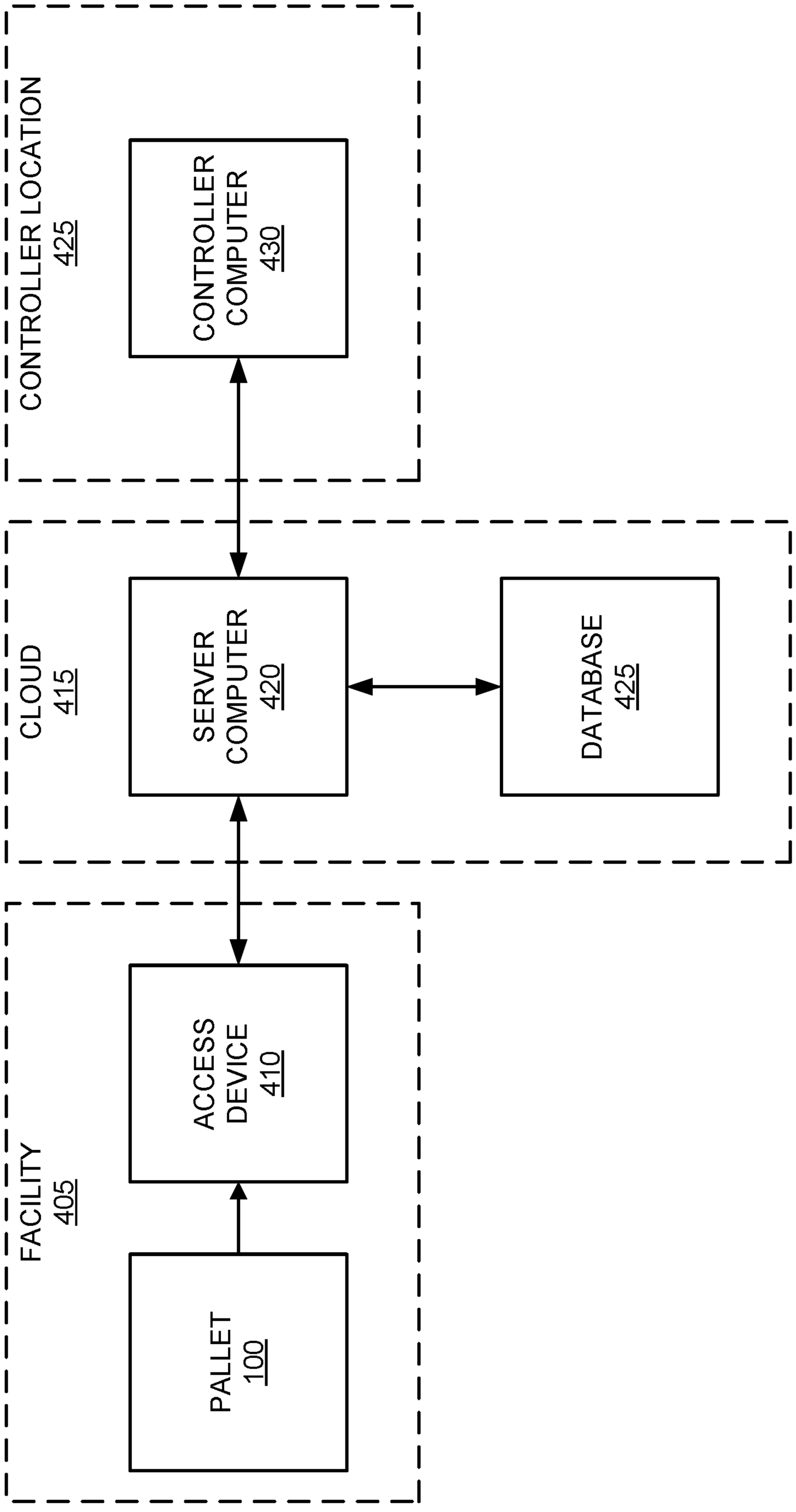
CONTROLLER LOCATION
425
CONTROLLER COMPUTER
430
CLOUD
415
SERVER COMPUTER
420
DATABASE
425
FACILITY
405
ACCESS DEVICE
410
PALLET
100

FIG. 4

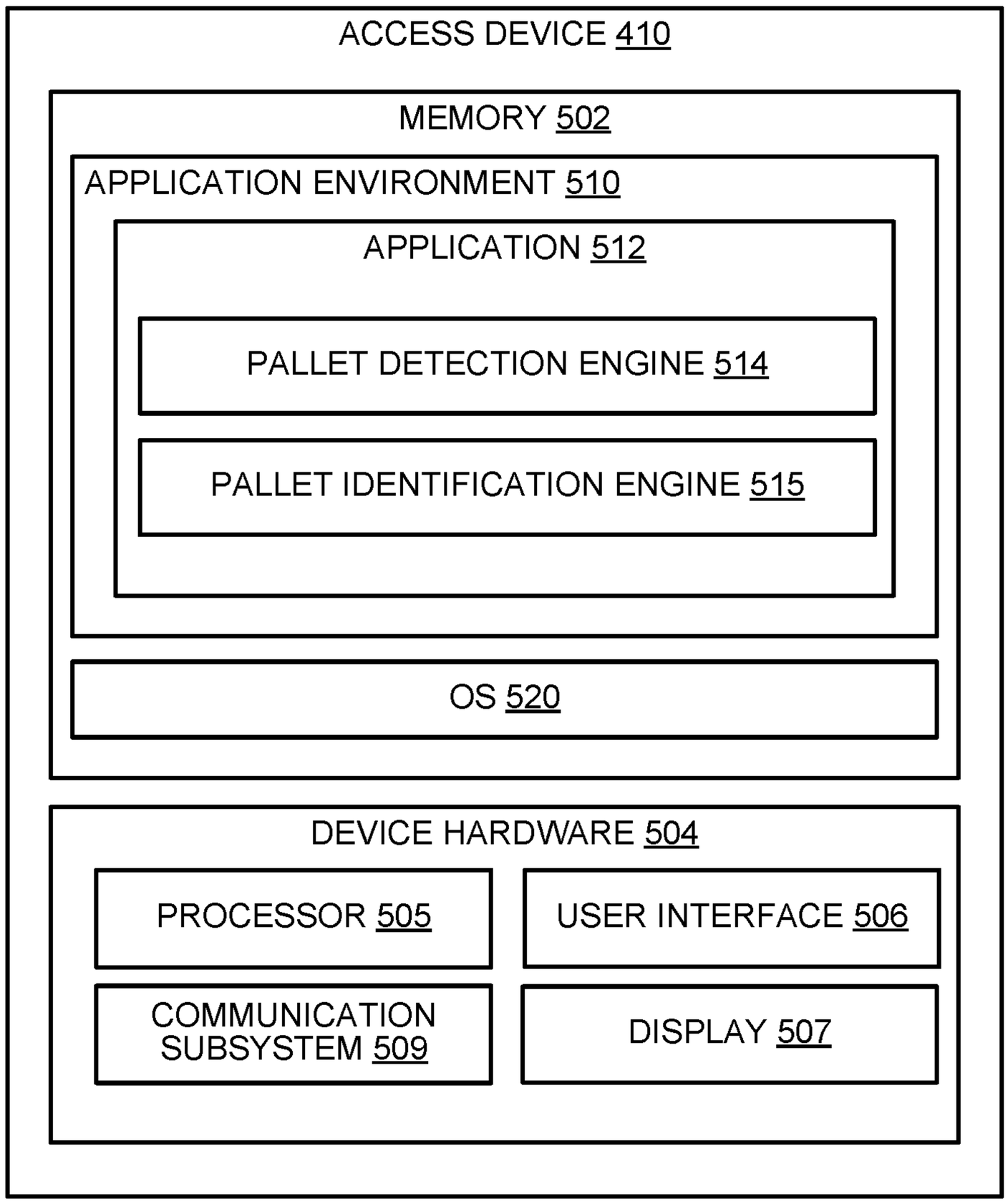
ACCESS DEVICE 410
MEMORY 502
APPLICATION ENVIRONMENT 510
APPLICATION 512
PALLET DETECTION ENGINE 514
PALLET IDENTIFICATION ENGINE 515
OS 520
DEVICE HARDWARE 504
PROCESSOR 505
USER INTERFACE 506
COMMUNICATION SUBSYSTEM 509
DISPLAY 507

FIG. 5

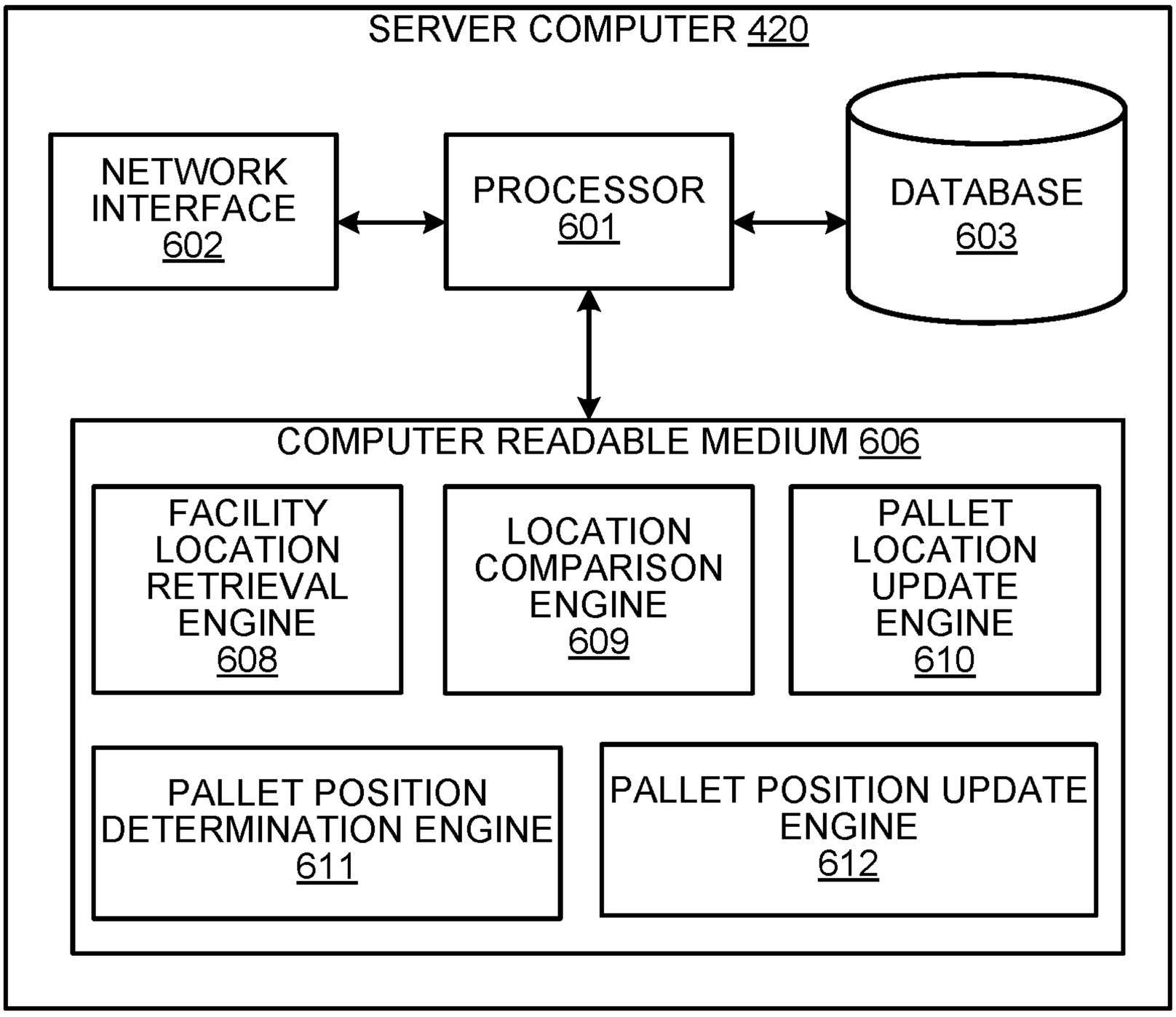
SERVER COMPUTER 420
NETWORK INTERFACE 602
PROCESSOR 601
DATABASE 603
COMPUTER READABLE MEDIUM 606
FACILITY LOCATION RETRIEVAL ENGINE 608
LOCATION COMPARISON ENGINE 609
PALLET LOCATION UPDATE ENGINE 610
PALLET POSITION DETERMINATION ENGINE 611
PALLET POSITION UPDATE ENGINE 612

FIG. 6

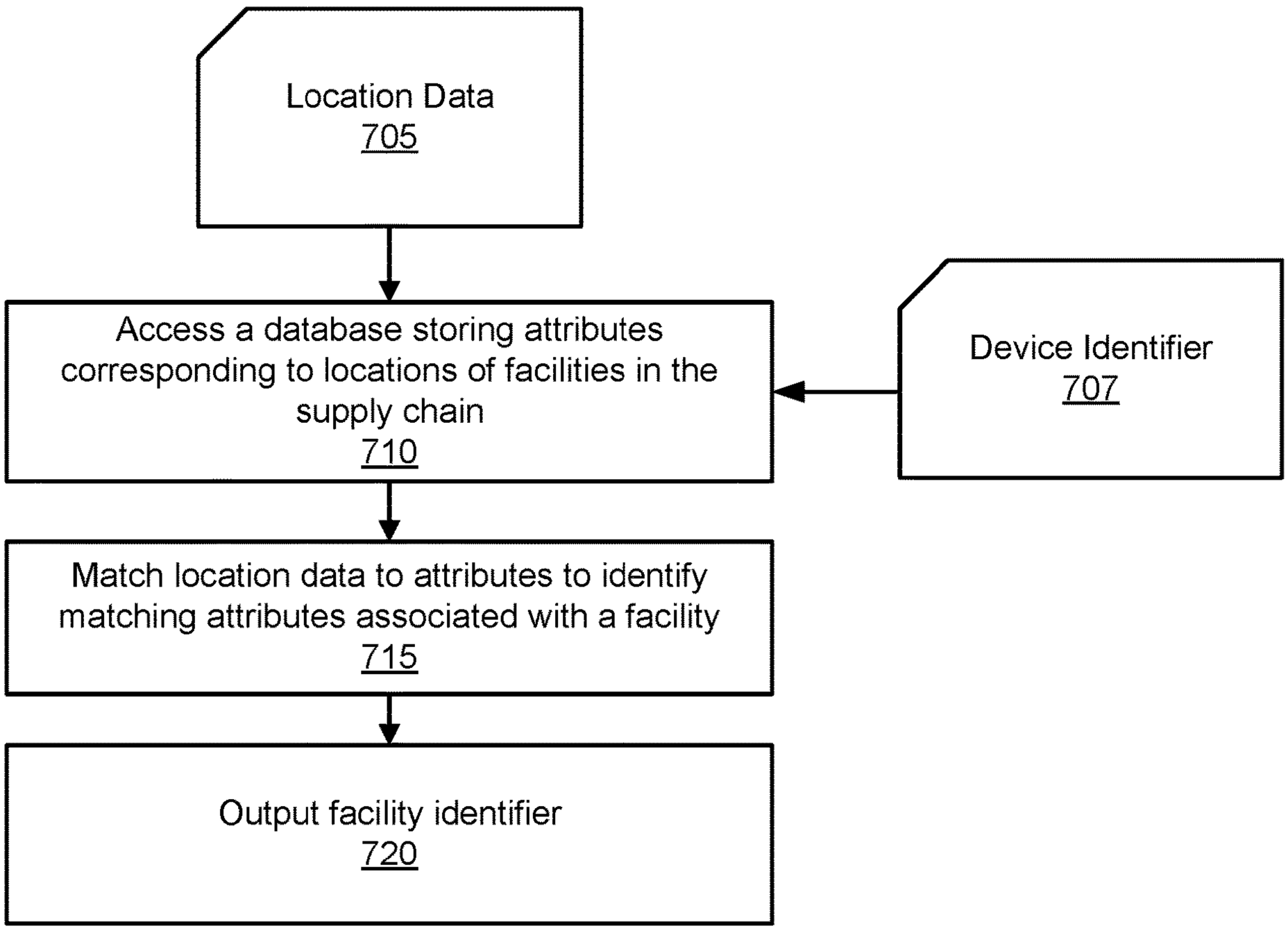
Location Data
705
Access a database storing attributes corresponding to locations of facilities in the supply chain
710
Device Identifier
707
Match location data to attributes to identify matching attributes associated with a facility
715
Output facility identifier
720

FIG. 7

SYSTEMS AND METHODS FOR FACILITY MATCHING AND LOCALIZATION

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application No. 62/500,461, filed May 2, 2017, the contents of which are hereby incorporated by reference in their entirety.

FIELD

The present disclosure generally relates to cargo transportation utilizing pallets, and more specifically to systems and methods for matching pallets to facilities and localizing pallets.

BACKGROUND

Monitoring pallet movement through a supply and distribution chain can aid in diagnosing issues with pallet loss and recovery, pallet damage and pallet cycle time. Reducing loss, damage and cycle time may have a material benefit for entities across the supply chain. Tracking pallets through the supply chain may also facilitate tracking of the assets they carry whenever an association between the two may be captured. A key requirement for tracking and tracing pallets through the supply chain is the ability to accurately assign a device attached to a pallet, such as an active tag including a BLE, WiFi, RFID, and/or cellular device that may also have GPS capabilities, to the correct known facility. Given the sometimes harsh constraints of the operating environment where pallets are primarily indoors, a technology such as GPS alone may be unreliable. Under certain conditions, satellite-based GPS may not work and no latitude and longitude information may be available. Even when satellite-based GPS provides accurate latitude and longitude, the latitude and longitude may not be resolved or mapped to the specific address of a facility that participates in the supply chain, rendering the latitude and longitude unusable. Without this mapping, actionable metrics about movement of assets in the supply chain may not be feasible.

BRIEF SUMMARY

Provided are methods, including computer-implemented methods, devices, and computer-program products applying systems and methods for facility matching and localization. According to some embodiments of the invention, the location of a pallet at a facility within a supply chain may be determined from location data received from a device (e.g., a beacon) on the pallet. As used herein, "location data" may include any data indicative of the location of the pallet, including, but not limited to, geographic data, pressure data, light sensor data, temperature data, humidity data, movement data, environmental condition data, etc. According to some embodiments, the methods, devices, and computer-program products described herein may intelligently generate, mark, or prioritize data based on heuristics that incorporate business context, such as average speed of movement of a forklift in a service center, so as to aid machine learning algorithms that drive facility mapping. In some embodiments, the position of the pallet within the facility may also be determined. Thus, the status of pallets may be monitored as they move through the supply chain.

According to some embodiments of the invention, a computer-implemented method is provided. The method comprises receiving, at a server computer located in a cloud, location data and a device identifier from a device affixed to a pallet. The location data was generated by hardware associated with the device. The location data may include geographic data, but may alternatively or additionally include any data indicative of the location of the pallet. The pallet is located at a facility of a plurality of facilities in a supply chain. The method further comprises accessing a database storing a plurality of sets of attributes indicative of a plurality of locations of the plurality of facilities in the supply chain. The method further comprises comparing the location data to the plurality of sets of attributes to identify a matching set of attributes associated with the facility of the plurality of facilities. The location data may match the set of attributes. The method further comprises outputting an identifier of the facility.

According to some embodiments of the invention, a device is provided. The device comprises one or more processors. The device further comprises a non-transitory computer-readable medium containing instructions that, when executed by the one or more processors, cause the one or more processors to perform operations including the steps of the methods described herein.

According to some embodiments of the invention, a computer-program product is provided. The computer-program product is tangibly embodied in a non-transitory machine-readable storage medium of a device. The computer-program product includes instructions that, when executed by one or more processors, cause the one or more processors to perform operations including the steps of the methods described herein.

This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in isolation to determine the scope of the claimed subject matter. The subject matter should be understood by reference to appropriate portions of the entire specification of this patent, any or all drawings, and each claim.

The foregoing, together with other features and embodiments, will become more apparent upon referring to the following specification, claims, and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Illustrative embodiments of the present invention are described in detail below with reference to the following drawing figures:

FIG. **1** is a bottom perspective view of a pallet with a beacon, in accordance with some embodiments.

FIG. **2** is a side view of a pallet with a load, in accordance with some embodiments.

FIG. **3** is a block diagram illustrating a pallet, in accordance with some embodiments.

FIG. **4** is a block diagram illustrating a system for facility matching and localization, in accordance with some embodiments.

FIG. **5** is a block diagram illustrating an access device, in accordance with some embodiments.

FIG. **6** is a block diagram illustrating a server computer, in accordance with some embodiments.

FIG. **7** is a flow chart illustrating a method for facility matching and localization, in accordance with some embodiments.

DETAILED DESCRIPTION

Certain aspects and embodiments of this disclosure are provided below. Some of these aspects and embodiments

may be applied independently and some of them may be applied in combination as would be apparent to those of skill in the art. In the following description, for the purposes of explanation, specific details are set forth in order to provide a thorough understanding of embodiments of the invention. However, it will be apparent that various embodiments may be practiced without these specific details. The figures and description are not intended to be restrictive.

The ensuing description provides exemplary embodiments only, and is not intended to limit the scope, applicability, or configuration of the disclosure. Rather, the ensuing description of the exemplary embodiments will provide those skilled in the art with an enabling description for implementing an exemplary embodiment. It should be understood that various changes may be made in the function and arrangement of elements without departing from the spirit and scope of the invention as set forth in the appended claims.

Specific details are given in the following description to provide a thorough understanding of the embodiments. However, it will be understood by one of ordinary skill in the art that the embodiments may be practiced without these specific details. For example, circuits, systems, networks, processes, and other components may be shown as components in block diagram form in order not to obscure the embodiments in unnecessary detail. In other instances, well-known circuits, processes, algorithms, structures, and techniques may be shown without unnecessary detail in order to avoid obscuring the embodiments.

Also, it is noted that individual embodiments may be described as a process which is depicted as a flowchart, a flow diagram, a data flow diagram, a structure diagram, or a block diagram. Although a flowchart may describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be re-arranged. A process is terminated when its operations are completed, but could have additional steps not included in a figure. A process may correspond to a method, a function, a procedure, a subroutine, a subprogram, etc. When a process corresponds to a function, its termination can correspond to a return of the function to the calling function or the main function.

The term "computer-readable medium" includes, but is not limited to, portable or non-portable storage devices, optical storage devices, and various other mediums capable of storing, containing, or carrying instruction(s) and/or data. A computer-readable medium may include a non-transitory medium in which data can be stored and that does not include carrier waves and/or transitory electronic signals propagating wirelessly or over wired connections. Examples of a non-transitory medium may include, but are not limited to, a magnetic disk or tape, optical storage media such as compact disk (CD) or digital versatile disk (DVD), flash memory, memory or memory devices. A computer-readable medium may have stored thereon code and/or machine-executable instructions that may represent a procedure, a function, a subprogram, a program, a routine, a subroutine, a module, a software package, a class, or any combination of instructions, data structures, or program statements. A code segment may be coupled to another code segment or a hardware circuit by passing and/or receiving information, data, arguments, parameters, or memory contents. Information, arguments, parameters, data, etc. may be passed, forwarded, or transmitted via any suitable means including memory sharing, message passing, token passing, network transmission, or the like.

Furthermore, embodiments may be implemented by hardware, software, firmware, middleware, microcode, hardware description languages, or any combination thereof. When implemented in software, firmware, middleware or microcode, the program code or code segments to perform the necessary tasks (e.g., a computer-program product) may be stored in a computer-readable or machine-readable medium. A processor(s) may perform the necessary tasks.

Pallets

A pallet may be a structure that supports physical assets for storage, presentation, handling, and/or transportation. As used herein, the term "pallet" may be used to describe any load carrier, including any type of platform, dolly, bin, container, and the like. The physical assets may be any physical assets, such as perishable or nonperishable physical goods. FIG. **1** is a bottom perspective view of a pallet **100**, in accordance with some embodiments. The pallet **100** may include a base **120** and legs **110**. The pallet **100** may be of any size, shape, and/or dimension, and may be made of any material or combination of materials. The base **120** and legs **110** may be of any size, shape, and/or dimensions. The base **120** may be flat and/or otherwise configured to support the shape and/or weight of the physical asset to be held on the pallet **100**. Although shown as having a particular design in FIG. **1**, it is contemplated that any design may be incorporated on or in the base **120**. For example, the base **120** may have smaller, larger, fewer, more, differently shaped, or differently placed spacing than those shown in FIG. **1**, depending on characteristics of the particular physical asset to be placed on the base **120** (e.g., weight, shape, temperature requirements, size, etc.).

The legs **110** may be sized and positioned to support the particular physical asset. In some embodiments, the legs **110** may be sized and positioned to allow a forklift, crane, or jacking device to engage and lift the pallet **100** between the legs **110**. Although shown and described as having three legs **110**, it is contemplated that the pallet **100** may have any suitable number of legs or no legs. For example, in some embodiments, the pallet **100** may include a base **120** on both the top and bottom of the pallet **100** with no legs. In another example, for heavier physical assets, the pallet **100** may include one or more additional legs centrally located with respect to the pallet **100** to prevent sagging of the base **120**. Further, although shown and described as being in a particular orientation and having a particular size, it is contemplated that the legs **110** may be of any size (e.g., height, length, width, depth, etc.) and/or orientation (e.g., parallel to each other, perpendicular to each other, etc.).

The pallet **100** may be made of any suitable material, depending on the characteristics of the particular physical asset to be supported by the pallet **100**. For example, the pallet **100** may be wooden, plastic, and/or metal. In some embodiments, the pallet **100** may be constructed to include unique physical features. In some embodiments, the base **120** may be made of a same or different material than the legs **110**. In some embodiments, the base **120** and the legs **110** may form a single unitary body (e.g., formed from a single mold). In some embodiments, the base **120** may be removable from one or more of the legs **110**.

In some embodiments, additional components may be integrated with the pallet **100**. For example, the underside of the pallet **100** may include a beacon **150**. The beacon **150** may include a number of different functionalities. For example, the beacon **150** may be programmed with the type of physical asset located on the pallet **100** and/or an identifier of the pallet **100**. The beacon **150** may further include or be in operable communication with one or more sensors

configured to monitor certain conditions of the pallet **100** (e.g., environmental conditions, movements, etc.). The beacon **150** is described further herein with respect to FIG. **3**. Although shown as being located in a particular position on the pallet **100**, it is contemplated that the beacon **150** may be located in any suitable position on the pallet **100**. FIG. **2** is a side view of another exemplary pallet **200** with a load **220** placed atop the pallet **200** for transportation, storage, presentation, etc. As used herein, pallet **100** may be referred to interchangeably with pallet **200**.

The pallet **100** and/or **200** may include components for performing multiple functions, as described herein. FIG. **3** is a block diagram illustrating the system components of the pallet **100** and/or **200**, in accordance with some embodiments. The pallet **100** and/or **200** may include a beacon **115** in operative communication with one or more external sensors **350**. The beacon **115** may include device hardware coupled to a memory **340**. The device hardware may include a processor **325**, a communication subsystem **330**, internal sensors **335**, and a power supply **345**. In some embodiments, the beacon **115** may be implemented as an active tag (e.g., an RFID tag). The beacon **115** may be associated with an identifier (e.g., an active tag identifier).

The processor **325** may be implemented as one or more integrated circuits (e.g., one or more single core or multicore microprocessors and/or microcontrollers), and may be used to control the operation of the beacon **115**. The processor **325** can execute a variety of programs in response to program code or computer-readable code stored in memory **340**, and can maintain multiple concurrently executing programs or processes. The communication subsystem **330** may include one or more transceivers and/or connectors that can be used by the beacon **115** to communicate with other devices (e.g., the external sensors **350**, access devices, etc.) and/or to connect with external networks. In some embodiments, the communication subsystem **330** may be configured to communicate using more than one protocol (e.g., protocol A **332** and protocol B **333**). Protocol A **332** and protocol B **333** may be two different wired or wireless communication protocols. For example, protocol A **332** and protocol B **333** may be selected from the group including Bluetooth, Bluetooth LE, near field communication (including IoT), WiFi, cellular communication, Ethernet, fiber optics, etc. The particular protocol used for a particular communication may be determined based on any of a number of factors, including availability, signal strength, type and/or amount of power received from or remaining on power supply **345**, data throughput, type of data to be communicated, size of data to be communicated, and the like.

The internal sensors **335** may include any movement-related, location-related, and/or environmental-related sensors. For example, the internal sensors **335** may include a global positioning system (GPS), an accelerometer, a gyroscope, a barometer, a thermometer, a humidity sensor, a light sensor, a microphone, combinations thereof, and/or the like. The internal sensors **335** may be coupled to the communication subsystem **330**, such that sensor measurements may be transmitted off of the pallet **100** to other devices or systems, as described further herein.

The memory **340** may be implemented using any combination of any number of non-volatile memories (e.g., flash memory) and volatile memories (e.g., DRAM, SRAM), or any other non-transitory storage medium, or a combination thereof media. In some embodiments, the memory **340** may be included in the processor **325**. The power supply **345** may include any wired or wireless power supply, such as a power outlet supply, a solar panel, and/or a battery.

The beacon **115** may be coupled to one or more external sensors **350** on the pallet **100** in some embodiments. The external sensors **350** may include, for example, a weight sensor and/or any of the sensors described above with respect to the internal sensors **335**. In one example, the weight sensor may include circuitry that measures the weight of a load on the pallet **100**. The weight sensor may transmit the weight to the beacon **115**. The beacon may use the communication subsystem **330** to transmit this data off of the pallet **100** to other devices or systems, as described further herein.

Systems for Facility Matching and Localization

In some cases, it may be desirable to identify a pallet's location in the supply chain. According to some embodiments of the invention, the location of a pallet anywhere in the supply chain may be determined. Conventional tracking solutions that provide accurate location traceability rely on installed infrastructure, such as proximity sensors and fixed manual or automated processes. In other words, the instrumentation is aimed at digitizing specific events, and the location of the digitizing device provides the location of the pallet. According to some embodiments of the invention, however, fixed infrastructure and minimum human compliance are needed to determine the pallet's location. For example, according to some embodiments, data may be captured that in turn determines the pallet's location based on the installation location of the data capturing device. Once the pallet's location has been identified, this information may be used to compute supply chain visibility metrics, such as inventory at any given location or region, dwell time, and velocity metrics between regions of the supply chain or between any set of nodes within the supply chain.

FIG. **4** is a block diagram illustrating a system for facility matching and localization, in accordance with some embodiments. The system may include a pallet **100**, an access device **410**, a server computer **420**, a database **425**, and a controller computer **430**. The pallet **100** and the access device **410** may be located at a facility **405** in the supply chain, such as a warehouse or store. The server computer **420** and the database **425** may be located in the cloud, such as at one or more offsite or third party locations with online or networked storage. The controller computer **430** may be located at a controller location **425**, such as at a pallet logistics and tracking company. Although shown and described with respect to a certain number of entities performing certain functions, it is contemplated that a greater or fewer number of entities may perform the functions described herein. For example, the functions of the server computer **420** may be spread across multiple server computers. In another example, the database **425** may be incorporated internally to the server computer **420**.

In some embodiments, the pallet **100** may communicate data to the access device **410** via a beacon or other communication medium. The data may cause the access device **410** to perform one or more operations. For example, the pallet **100** may communicate (or cause to be communicated) data indicative of its location (e.g., GPS coordinates, a latitude and longitude, triangulated coordinates, etc.). The pallet **100** may alternatively or additionally communicate an identifier that uniquely identifies the pallet **100** and/or the beacon. The data may be communicated, for example, by a Bluetooth, Bluetooth LE, WiFi, or cellular tag on the pallet **100**. When the access device **410** receives the signal, the access device **410** may process the data and forward it to the server computer **420**. In some embodiments, the access

device **410** may only communicate with the pallet **100** if the pallet **100** is a recognized or registered pallet. A pallet **100** may be recognized or registered based on, for example, a pallet identifier. In some embodiments, the pallet **100** may communicate a ping to the access device **410** that causes the access device **410** to capture an image of the pallet **100**. The image of the pallet **100** may then be used to correlate the pallet **100** to the location where it is positioned.

The access device **410** may be any suitable electronic user device. The access device **410** may include a communication device. A communication device may provide remote communication capabilities to a network. Examples of remote communication capabilities include using a mobile phone (wireless) network, wireless data network (e.g., 3G, 4G or similar networks), Wi-Fi, Wi-Max, or any other communication medium that may provide access to a network such as the Internet or a private network. Examples of devices include beacons, mobile phones (e.g., cellular phones), PDAs, tablet computers, net books, laptop computers, personal music players, handheld specialized readers, watches, fitness bands, wearables, ankle bracelets, rings, earrings, key fobs, physical wallets, glasses, containers, coffee mugs, takeout containers, etc., as well as automobiles with remote communication capabilities. The access device **410** may comprise any suitable hardware and software for performing such functions, and may also include multiple devices or components (e.g., when a device has remote access to a network by tethering to another device—i.e., using the other device as a modem—both devices taken together may be considered a single communication device). Further examples of an access device **410** may include a POS or point of sale device (e.g., POS terminals), cellular phone, PDA, personal computer (PCs), tablet PC, hand-held specialized reader, set-top box, electronic cash register (ECR), virtual cash registers (VCR), kiosk, and the like. In some embodiments, the access device **410** may be included in a pallet

The access device **410** may have an application installed that allows it to detect the pallet **100**, identify the pallet **100**, and upload location data from the pallet **100** to a server computer **420**. The access device **410** may be in communication with the server computer **420**. The access device **410** may forward the location data and the identifier of the pallet **100** to the server computer **420**. The server computer **420** may access a database **425** storing sets of attributes indicative of locations of facilities in the supply chain. For example, each facility in the supply chain may have an entry in the database **425** with a facility identifier (e.g., a name), a physical address (e.g., a street address), and a set of attributes (e.g., a latitude and longitude associated with the physical address, an ambient temperature, a wall color, a light level, a humidity level, etc.). The server computer **420** may compare the location data received from the pallet **100** to the sets of attributes to identify a matching set of attributes associated with the facility in which the pallet **100** is located. In the case of location coordinates, the location data may be within a threshold distance of the matching set of attributes (e.g., the GPS coordinates are within 0.1 miles of the facility's latitude and longitude).

The server computer **420** may store the identifier of the pallet **100** in association with the matched facility in the database **425**. For example, the server computer **420** may retrieve the entry in the database **425** associated with the matched facility and write the identifier of the pallet **100** in the record. In some embodiments, the identifier of the pallet **100** may be written to the record along with a timestamp indicating the date and time that the pallet **100** transmitted the location data that was ultimately matched to the facility. Thus, the record corresponding to a particular facility may include a plurality of identifiers of a plurality of pallets that were present at the facility at a plurality of times. In some embodiments, some or all of the functions of the server computer **420** may alternatively or additionally be performed by another entity or system, such as the access device **410**.

In some embodiments, the server computer **420** may provide these records from the database **425** to a controller computer **430**. The controller computer **430** may be an entity that tracks, maintains, and/or owns the pallet **100**. The controller computer **430** may use this data to determine whether the pallet **100** is at the correct facility **405**, to determine where the pallet **100** is in the supply chain, to determine the cycle time of the pallet **100**, to predict timing of the pallet **100** at a particular location, to compute supply chain visibility metrics, etc. In some embodiments, supply chain visibility metrics may include inventory at a given facility or in a given region, dwell time, and velocity metrics between regions or between facilities in the supply chain.

FIG. **5** is a block diagram illustrating an access device **410**, in accordance with some embodiments. The access device **410** may include device hardware **504** coupled to a memory **502**. Device hardware **504** may include a processor **505**, a communication subsystem **509**, and a user interface **506**. In some embodiments, device hardware **504** may include a display **507** (which can be part of the user interface **506**).

Processor **505** can be implemented as one or more integrated circuits (e.g., one or more single core or multicore microprocessors and/or microcontrollers), and is used to control the operation of the access device **410**. Processor **505** can execute a variety of programs in response to program code or computer-readable code stored in memory **502**, and can maintain multiple concurrently executing programs or processes. Communication subsystem **509** may include one or more transceivers and/or connectors that can be used by access device **410** to communicate with other devices (e.g., the pallet **100**) and/or to connect with external networks (e.g., to connect to the server computer **420**). User interface **506** can include any combination of input and output elements to allow a user to interact with and invoke the functionalities of the access device **410**. In some embodiments, user interface **506** may include a component such as display **507** that can be used for both input and output functions. Memory **502** can be implemented using any combination of any number of non-volatile memories (e.g., flash memory) and volatile memories (e.g., DRAM, SRAM), or any other non-transitory storage medium, or a combination thereof media. Memory **502** may store an operating system (OS) **520** and an application environment **510** where one or more applications reside including application **512** to be executed by processor **505**.

In some embodiments, application **512** may be an application that detects and identifies pallets, and/or transmits data received from a pallet to a server computer via a communication medium that may not be available to the pallet (e.g., cellular communications). Application **512** may include a pallet detection engine **514** and a pallet identification engine **515**. In some embodiments, one or more of these components can be provided by another application or component that is not part of application **512**.

The pallet detection engine **514** may be configured to, in conjunction with the processor **505** and the communication subsystem **509**, receive a ping (i.e., a brief signal) from a pallet in proximity to the access device **410**. In some

embodiments, the pallet may be configured to send a ping to the communication subsystem **509** when within a certain distance of the access device **410** (e.g., 10 feet). In some embodiments, the pallet may be configured to send a ping to the communication subsystem **509** when within any communication range of the access device **410** (e.g., 50 feet), and the pallet detection engine **514** may monitor the distance between the access device **410** and the pallet based on the pings. In some embodiments, when the ping is received by the pallet detection engine **514**, the pallet detection engine **514** may transmit a request for location data to the pallet. In some embodiments, when the ping is received by the pallet detection engine **514**, the pallet detection engine **514** sends a response ping indicating that the access device **410** is within communication range of the pallet. The response ping may cause the pallet to push the location data to the access device **410**. As used herein, "location data" may include any data indicative of the location of the pallet, including, but not limited to, geographic data, pressure data, light sensor data, temperature data, humidity data, movement data, environmental condition data, etc. Location data may be obtained using triangulation, as described further herein. In some embodiments, location data may be obtained using magnetometer data. In some embodiments, location data may be obtained from another device or pallet that has improved awareness of its location. For example, a first pallet may have a GPS fix and may assign a high confidence at being at a certain location, while a second pallet is deeper in the facility and does not have GPS access, WiFi access, or an uncertain cellular fix. If the first pallet detects a BLE signal from the second pallet, the location assignment and confidence may be transferred from the first pallet to the second pallet.

The pallet identification engine **515** may be configured to, in conjunction with the processor **505**, receive an identifier from a pallet with its location data. The pallet identification engine **515** may extract the identifier from the other data. In some embodiments, the pallet identification engine **515** may translate the identifier from a first format used by the pallet (i.e., a format stored on the beacon) into a second format used by external systems (e.g., the server computer, the controller computer, etc.). The pallet identification engine **515** may perform this translation by accessing a lookup table with entries corresponding to the received identifier and corresponding identifiers used by external systems.

FIG. **6** is a block diagram illustrating a server computer **420**, in accordance with some embodiments. Server computer **420** may include a processor **601** coupled to a network interface **602** and a computer readable medium **606**. Server computer **420** may also include or otherwise have access to a database **603** that may be internal or external to the server computer **420**.

Processor **601** may include one or more microprocessors to execute program components for performing the facility matching and localization functions of the server computer **420**. Network interface **602** may be configured to connect to one or more communication networks to allow the server computer **420** to communicate with other entities, such as the access device, the controller computer, etc. Computer readable medium **606** may include any combination of one or more volatile and/or non-volatile memories, for example, RAM, DRAM, SRAM, ROM, flash, or any other suitable memory components. Computer readable medium **606** may store code executable by the processor **601** for implementing some or all of the facility matching and localization functions of server computer **420**. For example, computer readable medium **606** may include code implementing a facility location retrieval engine **608**, a location comparison engine **609**, a pallet location update engine **610**, a pallet position determination engine **611**, and a pallet position update engine **612**.

The facility location retrieval engine **608** may be configured to, in conjunction with the processor **601**, access the database **603** to retrieve sets of attributes, including any data indicative of locations of facilities in the supply chain (e.g., coordinates, environmental conditions, visual features, etc.). In some embodiments, the facility location retrieval engine **608** may be configured to retrieve only sets of attributes corresponding to facilities that meet certain criteria. The criteria may include facilities within a certain region (e.g., an expected region of the pallet), type of facility (e.g., shipper facility, carrier facility, storefront, etc.), etc. This may reduce the number of facility locations to which the location data from the pallet needs to be compared, which may reduce processing time.

The location comparison engine **609** may be configured to, in conjunction with the processor **601**, receive location data from a pallet (e.g., via an access device) and the retrieved facility locations from the facility location retrieval engine **608**. The location comparison engine **609** may be configured to compare the location data to the sets of attributes of facilities to identify a matching facility location. In some embodiments, the location comparison engine **609** may convert disparate formats between the location data and the facility locations into the same format to facilitate accurate comparison. For example, if the location data includes GPS coordinates and the facility locations include physical addresses, the location comparison engine **609** may convert the physical addresses into GPS coordinates before comparing them. The matching facility location may be identified based on its location within a threshold distance of the location data. For example, the distance between the location data and the matching facility location may be less than a 0.15 mile threshold.

In some embodiments, the location comparison engine **609** may be configured to identify multiple potential matching facilities (e.g., all facilities within 0.1 miles of the location data) and provide a distance metric between the matching facilities and the location data, e.g., 0.05 miles from the location data, 0.07 miles from the location data, etc. The multiple potential matching facilities may be ranked from the closest to the location data to the furthest from the location data in some embodiments. The multiple potential matching facilities may further be ranked based on certain criteria, such as the expected location or facility of the pallet within the supply chain at the time the location data was transmitted. For example, some factors that may make one facility more likely than another may include matching transaction data, a more likely facility type (such as a service center being likely to ship to a manufacturer), a model of the supply chain (e.g., one manufacturing facility may be most likely to ship to a certain store), and/or the like. In some embodiments, the highest ranked facility of the multiple potential matching facilities may be selected as the matching facility. In some embodiments, the location comparison engine **609** may provide a degree of confidence for the matching facility. In some embodiments, there may be no potential facility matches based on criteria.

In some embodiments, the location comparison engine **609** may compare other data indicative of the location of the pallet to data associated with a facility to select and/or rank facilities. For example, in some embodiments, the location data received from the pallet may include environmental condition data, such as temperature data, movement data

(e.g., forklift speeds versus conveyor belt speeds), moisture data and humidity data (e.g., in a washing machine), etc. The location comparison engine **609** may translate this data into attributes associated with a facility in order to match the pallet to a known facility.

The pallet location update engine **610** may be configured to, in conjunction with the processor **601**, store the identifier of the pallet in association with the matching facility. For example, the pallet location update engine **610** may retrieve the entry in the database **603** associated with the matched facility (e.g., using a facility identifier, such as a name or a unique code) and write the identifier of the pallet in the record. In some embodiments, the identifier of the pallet may be written to the record along with a timestamp indicating the date and time that the pallet transmitted the location data that was ultimately matched to the facility. Thus, the record corresponding to a particular facility may include a plurality of identifiers of a plurality of pallets that were present at the facility at a plurality of times. This record may be used to analyze a particular facility's status and/or load in the supply chain.

Conversely, the pallet location update engine **610** may alternatively or additionally be configured to, in conjunction with the processor **601**, retrieve the entry in the database **603** associated with the identifier of the pallet and write the matched facility in the record. In some embodiments, the matched facility may be written to the record along with a timestamp indicating the date and time that the pallet transmitted the location data that was ultimately matched to the facility. Thus, the record corresponding to a particular pallet may include a plurality of facilities at which the pallet was present at a plurality of times. This record may be used to analyze a particular pallet's movement through the supply chain.

In some embodiments in which other location data (e.g., humidity data, temperature data, etc.) are provided by the pallet and specific attributes associated with a facility are previously unknown, the pallet location update engine **610** may create attributes in the record associated with the matching facility corresponding to the other location data provided by the pallet. In some embodiments, the pallet location update engine **610** may be self-learning and/or healing in that it may auto-learn attributes associated with a known location, auto-create known locations with well-known attributes while allowing administrators to review and update information, and/or auto-learn addresses based on third party services that can provide physical addresses and business and/or category information for a given set of facility data.

The pallet position determination engine **611** may be configured to, in conjunction with the processor **601**, receive the location data from the pallet (e.g., via an access device), along with the matching facility from the location comparison engine **609**. The pallet position determination engine **611** may be configured to retrieve from the database **603** a file including a floor plan of the matching facility. The pallet position determination engine **611** may be configured to map the location data from the pallet onto the floor plan of the facility to identify a position of the pallet within the facility (e.g., in a storage area, in a transportation area, at the loading dock, etc.). For example, the pallet position determination engine **611** may map a latitude and longitude of the pallet onto a visual representation of a floor plan of a facility to determine to which part of the floor plan the latitude and longitude correspond.

The pallet position update engine **612** may be configured to, in conjunction with the processor **601**, receive data indicative of the position of the pallet within the facility from the pallet position determination engine **611**. In some embodiments, the pallet position update engine **612** may be configured to store the position of the pallet along with its identifier in association with the matching facility in the database **603**. In some embodiments, the pallet position update engine **612** may be configured to retrieve the entry in the database **603** associated with the identifier of the pallet and write the position of the pallet along with the matched facility in the record.

Methods for Facility Matching and Localization

A variety of methods may be implemented by the above-described systems. FIG. **7** is a flow chart illustrating an exemplary method for facility matching and localization, in accordance with some embodiments. At process block **410**, location data **705** and a device identifier **707** are received at a server computer. The location data **705** may be received from a device (e.g., a beacon) affixed to a pallet. The location data was generated by hardware (e.g., a GPS) associated with the device. In some embodiments, the hardware may be located in a mobile device (e.g., a mobile phone). In some embodiments, the location data may include data generated using at least one WiFi router. For example, the location data may be generated by pinging three or more WiFi routers and triangulating the location of the device based on the signal strength. In some embodiments, the location data may include data generated using at least one cellular tower. For example, the location data may be generated by receiving data from three or more cellular towers and triangulating the location of the device based on the signal strength. In some embodiments, the device may not receive data from, or evoke a response from, the WiFi routers or the cellular towers. Instead, the triangulation may be based on the number of "sighted" WiFi routers and cellular towers and their relative signal strengths. In some embodiments, the location data may be generated using Bluetooth. In some embodiments, the location data may include a MAC ID. The pallet may be located at a facility of a plurality of facilities in a supply chain. Further at process block **410**, a database is accessed. The database may store one or more sets of attributes corresponding to locations of the plurality of facilities in the supply chain.

At process block **713**, the location data **705** is matched to the sets of attributes to identify a matching set of attributes associated with the facility in which the pallet is located. Further at process block **715**, if the location data **705** includes geographic data and the set of attributes includes geographic data, a threshold distance may be received, and the location data is determined to be within the threshold distance of the set of attributes. At process block **720**, the facility identifier **707** may be output. In some embodiments, the location data **705** and/or the device identifier **707** may further be stored in association with the facility identifier in the database.

In some embodiments in which the location data **705** includes geographic data, a file including a floor plan of the matching facility may further be retrieved from the database. The geographic data may be mapped onto the floor plan of the facility to identify a position of the device within the facility. Data indicative of the position of the device may be stored in the database.

As noted, the computer-readable medium may include transient media, such as a wireless broadcast or wired network transmission, or storage media (that is, non-transitory storage media), such as a hard disk, flash drive, compact disc, digital video disc, Blu-ray disc, or other computer-readable media. The computer-readable medium may be

understood to include one or more computer-readable media of various forms, in various examples.

In the foregoing description, aspects of the application are described with reference to specific embodiments thereof, but those skilled in the art will recognize that the invention is not limited thereto. Thus, while illustrative embodiments of the application have been described in detail herein, it is to be understood that the inventive concepts may be otherwise variously embodied and employed, and that the appended claims are intended to be construed to include such variations, except as limited by the prior art. Various features and aspects of the above-described invention may be used individually or jointly. Further, embodiments can be utilized in any number of environments and applications beyond those described herein without departing from the broader spirit and scope of the specification. The specification and drawings are, accordingly, to be regarded as illustrative rather than restrictive. For the purposes of illustration, methods were described in a particular order. It should be appreciated that in alternate embodiments, the methods may be performed in a different order than that described.

Where components are described as performing or being "configured to" perform certain operations, such configuration can be accomplished, for example, by designing electronic circuits or other hardware to perform the operation, by programming programmable electronic circuits (e.g., microprocessors, or other suitable electronic circuits) to perform the operation, or any combination thereof.

The various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, firmware, or combinations thereof. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention.

The techniques described herein may also be implemented in electronic hardware, computer software, firmware, or any combination thereof. Such techniques may be implemented in any of a variety of devices such as general purposes computers, wireless communication device handsets, or integrated circuit devices having multiple uses including application in wireless communication device handsets and other devices. Any features described as modules or components may be implemented together in an integrated logic device or separately as discrete but interoperable logic devices. If implemented in software, the techniques may be realized at least in part by a computer-readable data storage medium comprising program code including instructions that, when executed, performs one or more of the methods described above. The computer-readable data storage medium may form part of a computer program product, which may include packaging materials. The computer-readable medium may comprise memory or data storage media, such as random access memory (RAM) such as synchronous dynamic random access memory (SDRAM), read-only memory (ROM), non-volatile random access memory (NVRAM), electrically erasable programmable read-only memory (EEPROM), FLASH memory, magnetic or optical data storage media, and the like. The techniques additionally, or alternatively, may be realized at least in part by a computer-readable communication medium that carries or communicates program code in the form of instructions or data structures and that can be accessed, read, and/or executed by a computer, such as propagated signals or waves.

The program code may be executed by a processor, which may include one or more processors, such as one or more digital signal processors (DSPs), general purpose microprocessors, an application specific integrated circuits (ASICs), field programmable logic arrays (FPGAs), or other equivalent integrated or discrete logic circuitry. Such a processor may be configured to perform any of the techniques described in this disclosure. A general purpose processor may be a microprocessor; but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Accordingly, the term "processor," as used herein may refer to any of the foregoing structure, any combination of the foregoing structure, or any other structure or apparatus suitable for implementation of the techniques described herein. In addition, in some aspects, the functionality described herein may be provided within dedicated software modules or hardware modules configured for encoding and decoding, or incorporated in a combined encoder-decoder (CODEC).

What is claimed is:

1. A computer-implemented method comprising:

receiving, at a server computer, location data and a device identifier associated with a device affixed to a pallet, wherein:

the location data is indicative of a location of the pallet;

the pallet is located at a facility of one or more facilities in a supply chain; and

the facility is associated with a set of attributes indicative of a location of the facility and a facility identifier;

accessing a database storing one or more sets of attributes corresponding to the one or more facilities in the supply chain, wherein the database includes the set of attributes associated with the facility;

matching the location data to the set of attributes associated with the facility in the database to thereby identify the facility as a current location of the pallet;

associating the facility identifier with the device identifier when the location data is matched with the set of attributes; and

outputting the facility identifier.

2. The computer-implemented method of claim **1**, wherein the location data includes a set of coordinates, and wherein the method further comprises:

retrieving a file including a floor plan of the facility from the database;

mapping the set of coordinates onto the floor plan of the facility to identify a position of the device within the facility; and

storing data indicative of the position in the database.

3. The computer-implemented method of claim **1**, further comprising:

storing the a timestamp and the device identifier in the database record of the facility such that the record of the facility comprises a plurality of device identifiers of a plurality of pallets that are present at the facility.

4. The computer-implemented method of claim 1, wherein the device comprises a GPS device and the location data comprises GPS coordinates.

5. The computer-implemented method of claim 1, wherein the location data includes data generated using information received from at least one WiFi router.

6. The computer-implemented method of claim 1, wherein the location data includes data generated using information received from at least one cellular tower and the location data comprises triangulated coordinates.

7. A non-transitory computer-readable medium comprising instructions that, when executed by one or more processors, cause the one or more processors to perform operations comprising:

receiving location data and a device identifier associated with a device affixed to a pallet, wherein:

the location data is indicative of a location of the pallet;

the pallet is located at a facility of one or more facilities in a supply chain; and

the facility is associated with a set of attributes indicative of a location of the facility and a facility identifier;

accessing a database storing one or more sets of attributes corresponding to the one or more facilities in the supply chain, wherein the database includes the set of attributes associated with the facility;

matching the location data to the set of attributes associated with the facility in the database to thereby identify the facility as a current location of the pallet;

associating the facility identifier with the device identifier when the location data is matched with the set of attributes; and

outputting the facility identifier.

8. A system comprising:

one or more processors; and

one or more processors, cause the device to perform operations comprising:

receiving location data and a device identifier associated with a device affixed to a pallet, wherein:

the location data is indicative of a location of the pallet;

the pallet is located at a facility of one or more facilities in a supply chain; and

the facility is associated with a set of attributes indicative of a location of the facility and a facility identifier;

accessing a database storing one or more sets of attributes corresponding to the one or more facilities in the supply chain, wherein the database includes the set of attributes associated with the facility;

matching the location data to the set of attributes associated with the facility in the database to thereby identify the facility as a current location of the pallet;

associating the facility identifier with the device identifier when the location data is matched with the set of attributes; and

outputting the facility identifier.

9. The computer-implemented method of claim 1, wherein the set of attributes comprises a latitude and a longitude associated with a physical location of the facility.

10. The computer-implemented method of claim 9, wherein matching the location data to the set of attributes associated with the facility in the database comprises:

determining whether the location data is within a threshold distance of the latitude and longitude associated with the physical location of the facility.

11. The computer-implemented method of claim 1, wherein the location data comprises environmental conditions sensed by the device.

12. The computer-implemented method of claim 11, wherein the environmental conditions comprise temperature data, pressure data, humidity data, light sensor data, or movement data.

13. The computer-implemented method of claim 1, further comprising receiving the location data from a second device affixed to a second pallet in the facility.

14. The computer-implemented method of claim 1, wherein accessing a database storing the one or more sets of attributes corresponding to the one or more facilities in the supply chain comprises:

retrieving only sets of attributes corresponding to facilities in the one or more facilities that are located in an expected region of the pallet.

15. The computer-implemented method of claim 1, wherein accessing a database storing the one or more sets of attributes corresponding to the one or more facilities in the supply chain comprises:

retrieving only sets of attributes corresponding to facilities in the one or more facilities that are of an expected facility type for the pallet.

16. The computer-implemented method of claim 1, wherein matching the location data to the set of attributes associated with the facility in the database comprises:

identifying at least two facilities for which the associated sets of attributes match the location data; and

selecting the facility from the at least two facilities based on an expected location of the pallet.

17. The computer-implemented method of claim 1, wherein matching the location data to the set of attributes associated with the facility in the database comprises:

identifying at least two facilities for which the associated sets of attributes match the location data; and

selecting the facility from the at least two facilities based on an expected type of facility to receive the pallet.

18. The computer-implemented method of claim 1, further comprising:

identifying data in the location data that are not part of the set of attributes of the facility; and

adding new attributes to the set of attributes of the facility corresponding to the data.

19. The computer-implemented method of claim 1, wherein the location data is received from a mobile phone.

20. The computer-implemented method of claim 1, further comprising generating a physical address of the facility by sending the set of attributes to a third-party service and receiving the physical address and return.

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